

NASA Johnson Space Center

# Modular Integrated Stackable Layers (MISL) 1.1 Design Specification

Design Guideline Document

## 1. Scope

This document establishes the design guideline of the Modular Instrumentation Data Acquisition (MI-DAQ) system in utilization of several designs available in EV. The MI-DAQ provides the options to the customers depending on their system requirements i.e. a 28V interface power supply, a low power battery operated system, a low power microcontroller, a higher performance microcontroller, a USB interface, a Ethernet interface, a wireless communication, various sensor interfaces, etc. Depending on customer's requirements, the each functional board can be stacked up from a bottom level of power supply to a higher level of stack to provide user interfaces. The stack up of boards are accomplished by a predefined and standardized power bus and data bus connections which are included in this document along with other physical and electrical guidelines. This guideline also provides information for a new design options.

This specification is the product of a collaboration between NASA/JSC/EV and Texas A&M University. The goal of the collaboration is to open source the specification and allow outside entities to design, build, and market modules that are compatible with the specification. NASA has designed and is using numerous modules that are compatible to this specification. A limited number of these modules will also be released as open source designs to support the collaboration. The released designs are listed in the Applicable Documents.

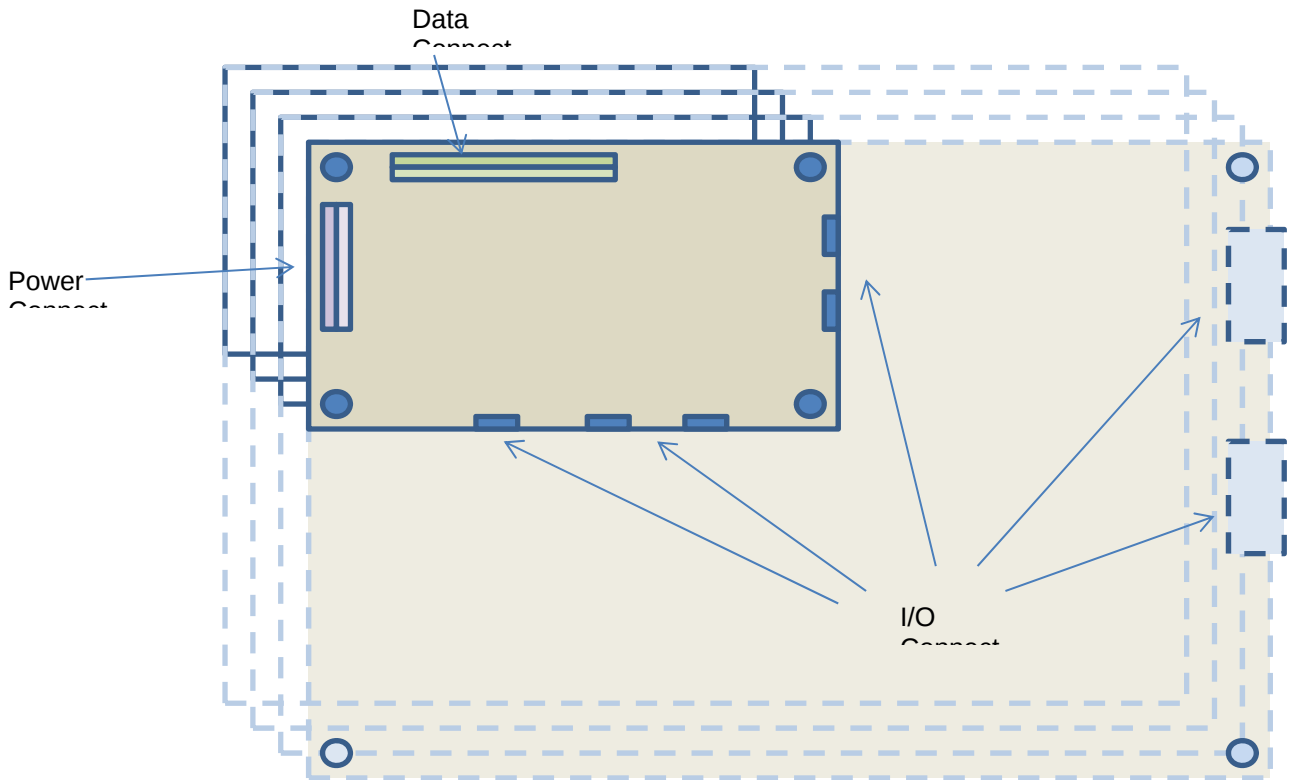
## 2. Applicable Documents

| Module Description            | Part Number    |
|-------------------------------|----------------|
| CPU - MSP430F5348A            | MISL110001-1.0 |
| CPU - Concerto                | MISL110003-1.1 |
| CPU - MSP430F6659             | MISL110004-1.1 |
| Power supply - Battery board  | MISL120001-1.0 |
| Power supply - 28VIN_Quad_Out | MISL120002-1.0 |
| Comm - W5200 Ethernet         | MISL130001-1.2 |
| Comm - GS1500M_803.11         | MISL130002-1.0 |
| Comm - WizFi630               | MISL130003-1.0 |
| Comm - Zigbee                 | MISL130004-1.0 |
| Comm - ISA100                 | MISL130005-1.0 |
| Comm - HI2130_1553            | MISL130007-1.0 |
| Demo module                   | MISL140001-1.0 |
| SubOrbital Sensor             | MISL140002-1.0 |
| 4-20mA Conditioning           | MISL140003-1.0 |
| Charge Amp                    | MISL140004-1.0 |
| Analog Voltage Input          | MISL140005-1.0 |
| PWM Control                   | MISL140006-1.0 |
| Debug                         | MISL150001-1.0 |
| Offset Stack                  | MISL150002-1.0 |
| Standoff                      | MISL150003-1.0 |

### 3. Guidelines

#### A. Board Dimension and Mounting Hole Locations

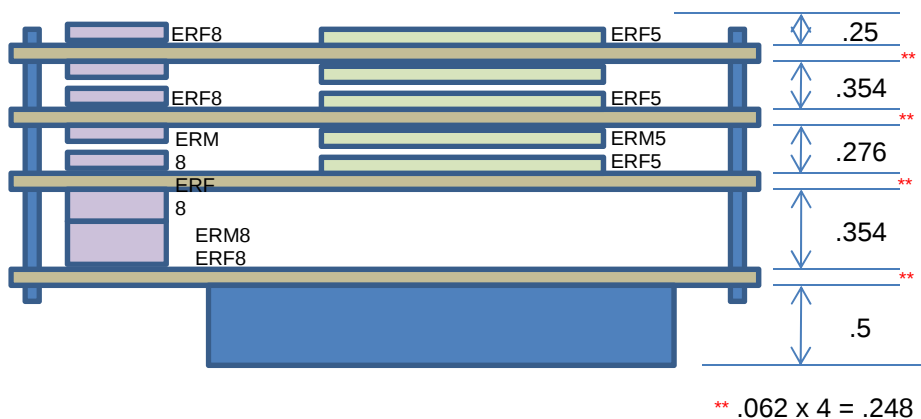
Board dimension can be user defined. However, four mounting-hole locations are predefined. The location of Power Bus Connector and Data Bus Connector are also predefined and they are located at the top-left corner of the board so that any user defined I/O connectors can be placed generally at the edges of right side and/or bottom side of the board. See the sketch below for just reference information.



## B. Board Stack-up and Board Clearance

Board stack-up is accomplished by the Power Bus Connector, Data Bus Connector, and four mounting holes. Board clearance is set depending on which connector set is used. There are four different height options between the boards that designer can select from the connectors available by the manufacture. Following section discuss about the bus connectors including the height of each connector and the mated height.

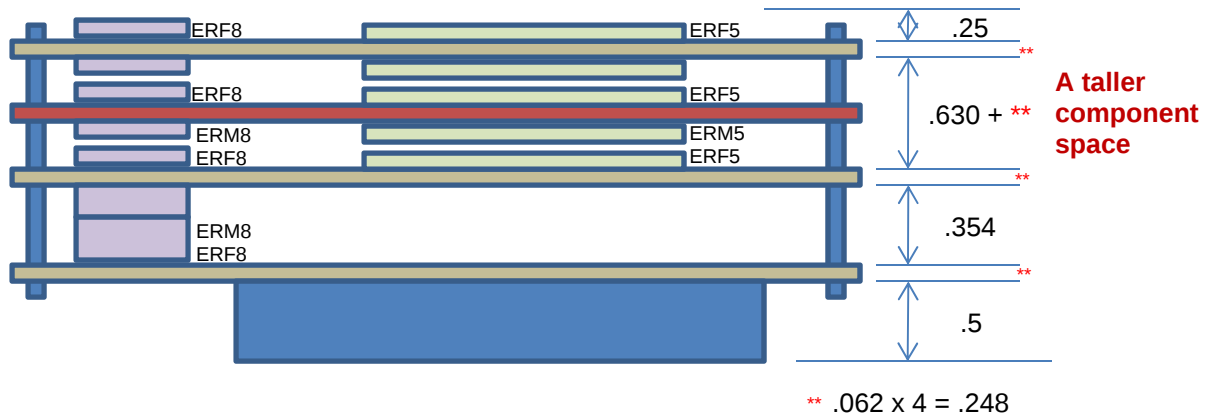
Guideline 1 (Board Clearance): Component heights should not be taller than the bus connector heights on either side of the board. Following sketch shows one example of stack-up options with its system height estimation.



Expected Total Height = 1.982 in

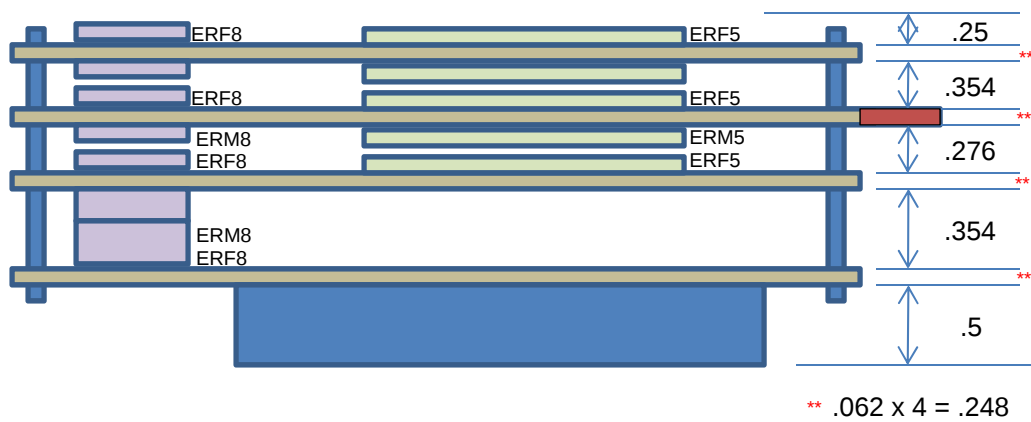
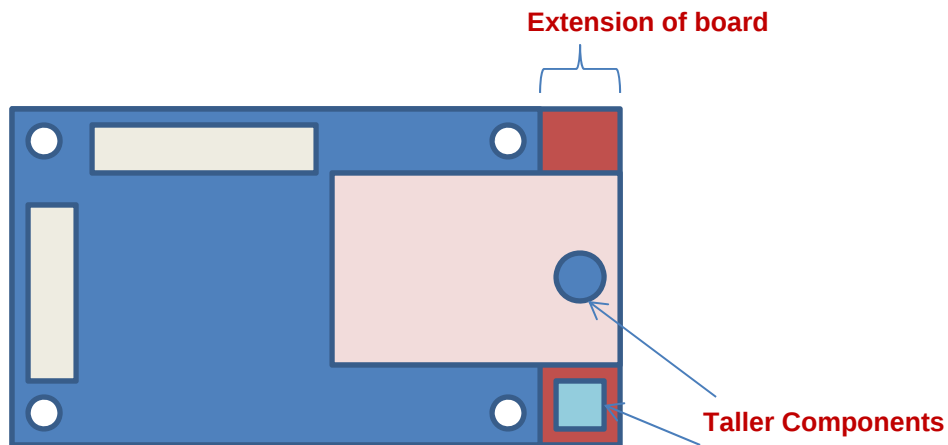
If a larger gap is required between the boards to fit a taller component, there can be a stack-up adapter board inserted between the connectors. See below as one of options. These adapter boards are not readily available. They should be built by the user.





Expected Total Height = 1.982

If a larger gap is required due to a taller component/connector on the edge of the board, a following concept is another option of designing the board and can maintain an optimum height of a system.



Expected Total Height = 1.982

### C. Bus Connector Information

Following Bus connectors are selected from SAMTEC.

#### ERM8/ERF8 for Power Bus Connector

.0315" pitch SMT

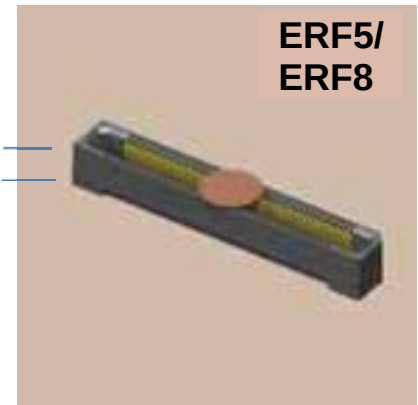
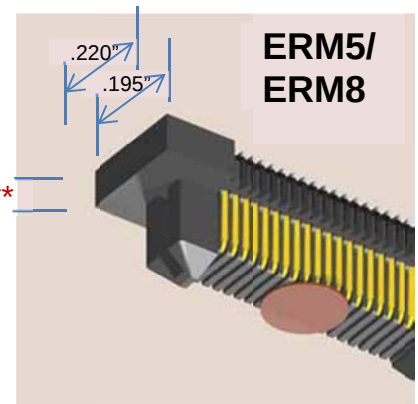
2.1A @85°C

#### ERM5/ERF5 for Data Bus Connector

.0197" pitch SMT

1.9A @80°C

194VAC rated



Following table show the height of two mated connectors. It shows in inches (mm).

| Mated Height: (Power Connector) (** maximum height of each connector) |                 |       |              |  |
|-----------------------------------------------------------------------|-----------------|-------|--------------|--|
| ERF8<br>LEAD<br>STYLE                                                 | ERM8 LEAD STYLE |       |              |  |
|                                                                       | -02.0 (.063)    | -04.0 | -05.0 (.181) |  |
| -05.0 (.200)                                                          | .276 (7,00)     | NA    | .394 (10,00) |  |
| -07.0 (.276)                                                          | .354 (9,00)     | NA    | .472 (12,00) |  |

| Mated Height: (Data Connector) (** maximum height of each connector) |                 |         |              |              |
|----------------------------------------------------------------------|-----------------|---------|--------------|--------------|
| ERF5<br>LEAD<br>STYLE                                                | ERM5 LEAD STYLE |         |              |              |
|                                                                      | -02.0 (.076)    | -04.0   | -05.0 (.194) |              |
| -05.0 (.193)                                                         | .276 (7,00)     | (9,00)  | .354         | .394 (10,00) |
| -07.0 (.272)                                                         | .354 (9,00)     | (11,00) | .433         | .472 (12,00) |

**Note:** There is no limit on the thickness of the printed circuit board. However, the connector has two alignment posts that are .043" long. In order to install both female and male connectors on top side and bottom side of the board respectfully, the two alignment post on the bottom of each connector should be trimmed (cut) to be installed properly. I.e. if the board is .062" thick, it is recommended to cut the posts in half approximately so that their combined length (~.04") of posts is much less than .062".

Detailed information can be found in the SAMTEC website. Followings are the shortcuts to their datasheets.

<http://www.samtec.com/ProductInformation/TechnicalSpecifications/Overview.aspx?series=ERF8>

<http://www.samtec.com/ProductInformation/TechnicalSpecifications/Overview.aspx?series=ERM8>

<http://www.samtec.com/ProductInformation/TechnicalSpecifications/Overview.aspx?series=ERF5>

<http://www.samtec.com/ProductInformation/TechnicalSpecifications/Overview.aspx?series=ERM5>

#### D. Electrical Bus Connection

##### 1) Power Bus Connector

Power Bus Connector voltages are originated by power supply boards (with exception of Vusb).

Following table shows the pin assignment of the Power Bus Connector in general and the pin functions used in current designs:

| Pin Number  | Pin Name | MI_28V PWR Board, P1(1) | MI_Battery Board, P1(2)                              |
|-------------|----------|-------------------------|------------------------------------------------------|
| 1,3,5,8     | 5Vdc     | 5Vdc                    | 5Vdc (Available only connected to 5V wall adapter)   |
| 2, 4,6,7    | 5VGND    | 5VGND                   | 5VGND* (Available only connected to 5V wall adapter) |
| 9           | 1.8Vdc   | Pass-Through            | Pass-Through                                         |
| 10          | 1V8GND   | Pass-Through            | Pass-Through                                         |
| 11          | 2V5GND   | Pass-Through            | Pass-Through                                         |
| 12          | VTEST    | VTEST                   | VTEST                                                |
| 13          | 2.5Vdc   | Pass-Through            | Pass-Through                                         |
| 14          | 3V3GND   | 3V3GND                  | 3V3GND*                                              |
| 15,17,19,21 | 3VGND    | 3VGND                   | 3VGND*                                               |
| 16,18,20,22 | 3.0Vdc   | 3.0Vdc                  | 3.0Vdc                                               |
| 23,25,27,29 | 3.3Vdc   | 3.3Vdc                  | 3.3Vdc                                               |
| 24,26,28    | 3V3GND   | 3V3GND                  | 3V3GND*                                              |
| 30,32       | 24VGND   | 24VGND                  | Pass-Through                                         |
| 31,34       | 24Vdca   | 24Vdca                  | Pass-Through                                         |
| 33          | Vusb     | Pass-Through            | Pass-Through                                         |
| 35,37,39    | 9-36Vrtn | 9-36Vrtn                | Pass-Through                                         |
| 36,38,40    | 9-36Vin  | 9-36Vin                 | Pass-Through                                         |

(1) B4, a inductor, is there to give an option to tie the internal ground to the chassis. All signal grounds are inductively coupled. A single point ground should be achieved individually on a board that is required.

(2) R25, a 1MOhm resistor, is there to give an option to tie the internal ground to the chassis. \*All signal grounds are tied at a single point on the board.



2) Data Bus Connector

- a. Following table shows the pin assignment of the Data Bus Connector in application of using a MSP430 MCU board:

| Data Bus Pin Number | Data Bus Pin Name | MSP430F5438AIP Z v1.1                      | MSP430F6659IPZ (w/ USB)                    | F28M36P63C (Concerto) (289 PIN ZWT BGA) | RM48L952 (337 ZWT BGA) |
|---------------------|-------------------|--------------------------------------------|--------------------------------------------|-----------------------------------------|------------------------|
| 1                   | ADC_A0, GPIO      | P6.0_PIN97 (A0 tied to Vtest on Power bus) | P6.0_PIN97 (A0 tied to Vtest on Power bus) | ADC1INA0_PIN_C13                        | AD1IN[0]_PIN_W14       |
| 2                   | ADC_A6, GPIO      | P6.6_PIN3                                  | P6.6_PIN3                                  | ADC2INA0_PIN_C8                         | AD1IN[6]_PIN_T19       |
| 3                   | ADC_A1, GPIO      | P6.1_PIN98                                 | P6.1_PIN98                                 | ADC1INA2_PIN_B13                        | AD1IN[1]_PIN_V17       |
| 4                   | ADC_A7, GPIO      | P6.7_PIN4                                  | P6.7_PIN4                                  | ADC2INA2_PIN_B8                         | AD1IN[7]_PIN_V14       |
| 5                   | ADC_A2, GPIO      | P6.2_PIN99                                 | P6.2_PIN99                                 | ADC1INA3_PIN_B12                        | AD1IN[2]_PIN_V18       |
| 6                   | ADC_A8, GPIO      | P7.4_PIN5                                  | P7.4_PIN5                                  | ADC2INA3_PIN_B9                         | AD1IN[8]_PIN_P18       |
| 7                   | ADC_A3, GPIO      | P6.3_PIN100                                | P6.3_PIN100                                | ADC1INA4_PIN_A11                        | AD1IN[3]_PIN_T17       |
| 8                   | ADC_A9, GPIO      | P7.5_PIN6                                  | P7.5_PIN6                                  | ADC2INA4_PIN_A9                         | AD1IN[9]_PIN_W17       |
| 9                   | ADC_A4, GPIO      | P6.4_PIN1                                  | P6.4_PIN1                                  | ADC1INA6_PIN_C12                        | AD1IN[4]_PIN_U18       |
| 10                  | ADC_A10, GPIO     | P7.6_PIN7                                  | P7.6_PIN7                                  | ADC2INA6_PIN_B10                        | AD1IN[10]_PIN_U17      |
| 11                  | ADC_A5, GPIO      | P6.5_PIN2                                  | P6.5_PIN2                                  | ADC1INA7_PIN_B11                        | AD1IN[5]_PIN_R17       |
| 12                  | ADC_A11, GPIO     | P7.7_PIN8                                  | P7.7_PIN8                                  | ADC2INA7_PIN_A10                        | AD1IN[11]_PIN_U19      |
| 13,14               | AGND              | AGND                                       | AGND                                       | AGND (VSSA)                             | AGND                   |
| 15                  | ADC_A12, GPIO     | N/C                                        | N/C                                        | ADC1INB0_PIN_A13                        | AD1IN[12]_PIN_T16      |
| 16                  | ADC_A14, GPIO     | N/C                                        | N/C                                        | ADC1INB4_PIN_C14                        | AD1IN[14]_PIN_R18      |

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|---------------------|-------------------|-----------------------|-------------------------|-----------------------------------------|-------------------------|
| 17                  | ADC_A13, GPIO     | N/C                   | N/C                     | ADC1INB3_PIN_B14                        | AD1IN[13]_PIN_T18       |
| 18                  | ADC_A15, GPIO     | N/C                   | N/C                     | ADC1INB7_PIN_B15                        | AD1IN[15]_PIN_P19       |
| 19                  | GPIO_1            | N/C                   | N/C                     | ADC2INB2_PIN_B7                         | AD1EVT_GPI_PIN_N 19     |
| 20                  | ADC_Vref+, GPIO   | P5.0_PIN9             | P5.0_PIN9               | ADC1VrefHI & ADC1VrefHI_EXT             | ADREFHI_PIN_V15         |
| 21                  | GPIO_2            | N/C                   | N/C                     | ADC2INB4_PIN_B6                         | AV2EVT_GPIO_PIN_V10     |
| 22                  | ADC_Vref-, GPIO   | P5.1_PIN10            | P5.1_PIN10              | ADC2VrefHI & ADC2VrefHI_EXT             | ADREFLO_PIN_V16         |
| 23                  | GPIO_3            | P1.7_PIN24            | P1.7_PIN24              | ADC2INB6_PIN_A5                         | AD1IN[16]_PIN_V13       |
| 24                  | GPIO_33           | P1.0_PIN17            | P1.0_PIN17              | PH6_GPIO54_QEP3_PIN_R17                 | N2HET1[4]_GPIO_PIN_B12  |
| 25                  | GPIO_4            | P8.7_PIN67            | P8.7_PIN67              | PA6_GPIO6_I2C1SCL_PIN_F2                | N2HET2[13]_GPIO_PIN_C5  |
| 26                  | GPIO_34           | P1.1_PIN18            | P1.1_PIN18              | PH7_GPIO55_QEP3_PIN_P18                 | N2HET1[16]_GPIO_PIN_A4  |
| 27                  | GPIO_5            | P9.6_PIN74            | P9.0_PIN68              | PA7_GPIO7_I2C1SDA_PIN_F1                | GIOA[4]_PIN_A6          |
| 28                  | GPIO_35           | P1.2_PIN19            | P1.2_PIN19              | PJ0_GPIO56_QEP3_PIN_W16                 | N2HET1[17]_GPIO_PIN_A13 |
| 29                  | GPIO_6            | P9.7_PIN75            | P9.7_PIN75              | PF5_GPIO37_CCP2_C AP2_PIN_U11           | GIOA[5]_EXRCLKIN_PIN_B5 |

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|---------------------|-------------------|-----------------------|-------------------------|-----------------------------------------|----------------------------------------------|
| 30                  | GPIO_36           | P1.3_PIN20            | P1.3_PIN20              | PJ1_GPIO57_QEP3_PIN_V13                 | N2HET1[18]_GPIO_PIN_J1                       |
| 31                  | GPIO_7            | P10.6_PIN82           |                         | PB6_GPIO14_CCP_PWM_PIN_H4               | GIOB[2]_PIN_F2                               |
| 32                  | GPIO_37           | P1.4_PIN21            | P1.4_PIN21              | PJ4_GPIO60_CCP4_PWM8A_PIN_V15           | N2HET1[19]_GPIO_PIN_B13                      |
| 33                  | GPIO_8            | P10.7_PIN83           |                         | PJ7_GPIO63_CCPO_PWM_PIN_H17             | <b>MIBSPI1NCS</b> [4]_N2HET1[15]_GPIO_PIN_N1 |
| 34                  | GPIO_38           | P1.5_PIN22            | P1.5_PIN22              | PH1_GPIO49_CCP7_CAP6_PIN_U8             | N2HET1[20]_GPIO_PIN_P2                       |
| 35                  | GPIO_9_SENA_SCLK  | P9.0_PIN68            | P9.1_PIN69              | PD7_GPIO23_MFSXA_I2C1SCL_PIN_W17        | <b>MIBSPI1NCS</b> [3]_N2HET1[21]_GPIO_PIN_J3 |
| 36                  | GPIO_39_CLK       | P1.6_PIN23            | P1.6_PIN23              | PH0_GPIO48_CCP6_CAP5_PIN_V10            | N2HET1[21]_GPIO_PIN_H4                       |
| 37                  | GPIO_10_SIMO_SDA  | P9.1_PIN69            | P9.5_PIN73              | PD4_GPIO20_MDXA_CAN1TX_U3TX_PIN_U16     | <b>MIBSPI1SIMO</b> _GPIO_PIN_F19             |
| 38                  | GND               | GND                   | GND                     | GND                                     | GND                                          |
| 39                  | GPIO_11_SOMI_SCL  | P9.2_PIN70            | P9.6_PIN74              | PD5_GPIO21_MDRA_CAN1RX_U3RX_PIN_U17     | <b>MIBSPI1SOMI</b> _GPIO_PIN_G18             |
| 40                  | GPIO_40_CLK       | P2.0_PIN25            | P3.0_PIN42              | PB7_GPIO15_ExtNMI_PIN_H3                | GIOA[3]_N2HET2[2]_PIN_E1                     |

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|----------------------------|--------------------------|------------------------------|--------------------------------|------------------------------------------------|-------------------------------|
| 41                         | GPIO_12_SCLK_S<br>ENA    | P9.3_PIN71                   | P9.4_PIN72                     | PD6_GPIO22_MCLKXA_I2C1SDA_PIN_V17              | MIBSPI1CLK_GPIO_PIN_F18       |
| 42                         | GPIO_41                  | P2.1_PIN26                   | P3.1_PIN43                     | PP3_GPIO107_I2C0SDA_QEP_PIN_F18                | GIOA[6]_N2HET2[4]_PIN_H3      |
| 43                         | GPIO_13_TXD_S<br>IMO     | P9.4_PIN72                   | P9.2_PIN70                     | PA1_GPIO1_U0TX_I2C1SDA_ECAPP6_PIN_E3           | LINTX_GPIO_PIN_B7             |
| 44                         | GPIO_42                  | P2.2_PIN27                   | P3.2_PIN44                     | PP2_GPIO106_I2C0SCA_QEP_PIN_F17                | GIOA[7]_N2HET2[6]_M1          |
| 45                         | GPIO_14_RXD_S<br>OMI     | P9.5_PIN73                   | P9.3_PIN71                     | PA0_GPIO0_U0RX_I2C1SCL_PIN_D1                  | LINRX_GPIO_PIN_A7             |
| 46                         | GPIO_43                  | P2.3_PIN28                   | P3.3_PIN45                     | PJ3_GPIO59_CCP6_PWM7B_PIN_U15                  | GIOB[4]_PIN_G1                |
| 47                         | GPIO_15_SENA_SCLK        | P10.0_PIN76                  | P8.4_PIN62                     | PB3_GPIO11_SSI2FSS_PIN_G1                      | SPI2NENA_GPIO_PIN_D3          |
| 48                         | GPIO_45_CLK              | P2.4_PIN29                   | P3.4_PIN46                     | PJ2_GPIO58_CCP0_PWM7A_PIN_V12                  | GIOB[5]_PIN_G2                |
| 49                         | GPIO_16_SIMO_SDA         | P10.1_PIN77                  | P8.2_PIN60                     | PB0_GPIO8_SSI2TX_U4TX_CAN1TX_PIN_G4            | SPI2SIMO_GPIO_PIN_D1          |
| 50                         | GPIO_46_CLK              | P2.6_PIN31                   | P2.6_PIN23                     | PH3_GPIO51_PIN_U7                              | GIOB[6]_PIN_J2                |
| 51                         | GPIO_17_SOMI_SCL         | P10.2_PIN78                  | P8.3_PIN61                     | PB1_GPIO9_SSI2RX_PIN_G3                        | SPI2SOMI_GPIO_PIN_D2          |
| 52                         | GPIO_47                  | P2.7_PIN32                   | P2.7_PIN24                     | PF4_GPIO36_CCP_PIN_U14                         | GIOB[7]_PIN_F1                |
| 53                         | GND                      | GND                          | GND                            | GND                                            | GND                           |

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|----------------------------|--------------------------|------------------------------|--------------------------------|------------------------------------------------|-----------------------------------------------------|
| 54                         | GPIO_48                  | P4.0_PIN43                   | P4.0_PIN50                     | PC4_GPIO68_CCP5_P<br>WM_PIN_W8                 | GPIO_PIN_E19                                        |
| 55                         | GPIO_18_SCLK_S<br>ENA    | P10.3_PIN79                  | P8.1_PIN59                     | PB2_GPIO10_SSI2CLK<br>_U4RX_PIN_G2             | SPI2CLK_GPIO_PIN_<br>E2                             |
| 56                         | GPIO_49                  | P4.1_PIN44                   | P4.1_PIN51                     | PC5_GPIO69_CCP3_P<br>WM_PIN_W7                 | GPIO_PIN_B6                                         |
| 57                         | GPIO_19_TXD_S<br>MO      | P10.4_PIN80                  | P2.4_PIN21                     | PC7_GPIO71_U1TX_P<br>N_V9                      | SCITX_N2HET1[13]<br>GPIO_PIN_N2                     |
| 58                         | GPIO_50                  | P4.2_PIN45                   | P4.2_PIN52                     | PR7_GPIO127_PWM_<br>PIN_K3                     | GPIO_PIN_W6                                         |
| 59                         | GPIO_20_RXD_S<br>OMI     | P10.5_PIN81                  | P2.5_PIN22                     | PC6_GPIO70_U1RX_P<br>N_V8                      | SCIRX_N2HET1[6]<br>GPIO_PIN_W3                      |
| 60                         | GPIO_51                  | P4.3_PIN46                   | P4.3_PIN53                     | PS0_GPIO128_PWM_<br>PIN_K2                     | GPIO_PIN_T12                                        |
| 61                         | GPIO_44                  | P2.5_PIN30                   | P3.5_PIN47                     | PH4_GPIO52_PIN_U1<br>0                         | CAN2TX_GPIO_PIN_<br>H2                              |
| 62                         | GPIO_52                  | P4.4_PIN47                   | P4.4_PIN54                     | PS1_GPIO129_PWM_<br>PIN_L3                     | GPIO_PIN_E16                                        |
| 63                         | GPIO_21_SENA_<br>SCLK    | P3.6_PIN41                   | P8.1_PIN59                     | PE0_GPIO24_SSI1CLK<br>_EQEP2A_PIN_W10          | MIBSPI3CLK_GPIO_<br>PIN_V9                          |
| 64                         | GPIO_53                  | P4.5_PIN48                   | P4.5_PIN55                     | PE5_GPIO29_SCITXDA<br>_PIN_U19                 | GPIO_PIN_H17                                        |
| 65                         | GPIO_22_SIMO_<br>SDA     | P3.7_PIN42                   | P8.5_PIN65                     | PF0_GPIO32_I2CASDA<br>_I2C0SDA_PIN_D19         | I2C_SDA_MIBSPI3N<br>CS[2]_N2HET1[27]<br>GPIO_PIN_B2 |
| 66                         | GPIO_54                  | P4.6_PIN49                   | P4.6_PIN56                     | PS2_GPIO130_PWM_<br>PIN_L2                     | GPIO_PIN_G17                                        |

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|---------------------|-------------------|-----------------------|-------------------------|-----------------------------------------|-----------------------------------------------|
| 67                  | GPIO_23_SOMI_SCL  | P5.4_PIN51            | P8.6_PIN66              | PF1_GPIO33_I2CASCL_I2C0SCL_PIN_E17      | I2C_SCL_MIBSPI3NC S[3]_N2HET1[29]_GPIO_PIN_C3 |
| 68                  | GPIO_55_CLK       | P4.7_PIN50            | P4.7_PIN57              | PE4_GPIO28_SCIRXDA_PIN_T18              | CAN3TX_GPIO_PIN_M18                           |
| 69                  | GPIO_24_SCLK_SENA | P5.5_PIN52            | P8.4_PIN62              | PE1_GPIO25_SSI1FSS_EQEP2B_PIN_W9        | MIBSPI3NENA_N2HET1[31]_GPIO_PIN_W9            |
| 70                  | GND               | GND                   | GND                     | GND                                     |                                               |
| 71                  | GPIO_25_TXD_SIMO  | P5.6_PIN53            | P8.2_PIN60              | PE3_GPIO27_SSI1TX_U2TX_EQEP2S_PIN_V6    | MIBSPI3SIMO_GPIO_PIN_W8                       |
| 72                  | GPIO_56_CLK       | P11.0_PIN84           | P5.6_PIN16              | PS3_GPIO131_PWM_PIN_M3                  | CAN3RX_GPIO_PIN_M19                           |
| 73                  | GPIO_26_RXD_SOMI  | P5.7_PIN54            | P8.3_PIN61              | PE2_GPIO26_SSI1RX_U2RX_EQEP2I_U6        | MIBSPI3SOMI_GPIO_PIN_V8                       |
| 74                  | GPIO_57_CLK       | P11.1_PIN85           | P5.7_PIN88              | PB5_GPIO13_CAN1RX_PIN_M4                | CAN1RX_GPIO_PIN_B10                           |
| 75                  | GPIO_27_TXD_SIMO  | P3.4_PIN39            | P2.4_PIN21              | PP0_GPIO104_I2C_PIN_G17                 | CAN2RX_GPIO_PIN_H1                            |
| 76                  | GPIO_58_CLK       | P11.2_PIN86           |                         | PB4_GPIO12_CAN1TX_PIN_N4                | CAN1TX_GPIO_PIN_A10                           |
| 77                  | GPIO_28_SIMO_SDA  | MOSI_P3.1_PIN34 (uSD) | P2.1_PIN18 (uSD)        | PD0_GPIO16_SPISIMOA_U2RX_PIN_F16 (uSD)  | SPI4SIMO_N2HET1[2]_GPIO_PIN_W5                |
| 78                  | GPIO_59           | P8.0_PIN57            | P8.0_PIN57              | PH2_GPIO50_PIN_V7                       | N2HET1[23]_GPIO_PIN_J4                        |
| 79                  | GPIO_29_SOMI_SCL  | MISO_P3.2_PIN35 (uSD) | P2.2_PIN19 (uSD)        | PD1_GPIO17_SPISOMIA_U2TX_PIN_F19 (uSD)  | SPI4SOMI_N2HET1[5]_GPIO_PIN_V6                |
| 80                  | GPIO_60           | P8.1_PIN58            | P3.6_PIN48              | PJ5_GPIO61_CCP2_PWM8B_PIN_V14           | N2HET1[25]_GPIO_PIN_M3                        |
| 81                  | GND               | GND                   | GND                     | GND                                     | GND                                           |
| 82                  | GPIO_61           | P8.2_PIN59            | P3.7_PIN49              | PJ6_GPIO62_CCP1_PWM9A_PIN_V16           | N2HET1[27]_GPIO_PIN_A9                        |
| 83                  | GPIO_30_SCLK_SENA | SCLK_P3.3_PIN36 (uSD) | P2.3_PIN20 (uSD)        | PD2_GPIO18_SPICLKCAN0RX_PIN_W5 (uSD)    | SPI4CLK_N2HET1[0]_GPIO_PIN_K18                |

| Data Bus Pin Number | Data Bus Pin Name | MSP430F5438AIP Z v1.1 | MSP430F6659IPZ (w/ USB) | F28M36P63C (Concerto) (289 PIN ZWT BGA) | RM48L952 (337 ZWT BGA)         |
|---------------------|-------------------|-----------------------|-------------------------|-----------------------------------------|--------------------------------|
| 84                  | GPIO_62           | P8.3_PIN60            | P5.3_PIN31              | PC0_GPIO64_QEP_PIN_V4                   | N2HET1[29]_GPIO_PIN_A3         |
| 85                  | GPIO_31_SENA_SCLK | SENA_P3.0_PIN33 (uSD) | P2.0_PIN17 (uSD)        | PD3_GPIO19_SPISTEAL_CAN0TX_PIN_W6 (uSD) | SPI4NENA_N2HET1[1]_GPIO_PIN_V2 |
| 86                  | GPIO_63           | P8.4_PIN61            | P5.4_PIN32              | PC1_GPIO65_QEP_PIN_W4                   | N2HET1[31]_GPIO_PIN_J17        |
| 87                  | GPIO_32_RXD_SOMI  | P3.5_PIN40            | P2.5_PIN22              | PP1_GPIO105_I2C_PIN_G16                 | GPIO_PIN_L19                   |
| 88                  | GPIO_64           | P8.5_PIN65            | P5.5_PIN33              | PC2_GPIO66_QEP_PIN_U5                   | N2HET2[11]_GPIO_PIN_C4         |
| 89                  | JTAG_TDO          |                       |                         | TDO_PIN_T19                             | TDO_PIN_C18                    |
| 90                  | GPIO_65           | P8.6_PIN66            | P5.2_PIN28              | PC3_GPIO67_QEP_PIN_V5                   | GPIO_PIN_E17                   |
| 91                  | STACK_TDI1        |                       |                         | TDI_PIN_K19                             | TDI_PIN_A17                    |
| 92                  | GPIO_66           | P7.3_PIN56            |                         | PA4_GPIO4_CAN0RX_PIN_F4                 | GPIO_PIN_H16                   |
| 93                  | STACK_TDI2        |                       |                         | TDI2                                    | TDI2                           |
| 94                  | GPIO_67           | P7.2_PIN55            |                         | PA5_GPIO5_CAN0TX_PIN_F3                 | GPIO_PIN_G16                   |
| 95                  | JTAG_TMS          |                       |                         | TMS_PIN_M19                             | TMS_PIN_C19                    |
| 96                  | GPIO_68_XTIN      | P5.2_PIN89            | P7.2_PIN84              | PP4_GPIO108_I2C1SCL_QEP_PIN_C19         | EXTCLKIN2_PIN_B5               |
| 97                  | JTAG_TCK          |                       |                         | TCK_PIN_L19                             | TCK_PIN_B18                    |
| 98                  | GPIO_69_XTOUT     | P5.3_PIN90            | P7.3_PIN85              | PP5_GPIO109_I2C1SDA_QEP_PIN_C18         | ECLK_GPIO_PIN_A12              |
| 99                  | nRESET            | NRST_PIN96            | NRST_PIN96              | NTRST_PIN_N19                           | NTRST_PIN_D18                  |
| 100                 | TEST              |                       |                         |                                         | TEST_PIN_U2                    |





